

Beamlines for school competition 2024

Data sonification of the T9 beamline for the purpose of musical composition

By Team Synthotron

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Abstract

Presented is a proposition for an experiment to test the viability of the T9 beamline as a tool for musical composition. Expanding on limited research in this area, the project aims to explore the union of physics and music through data sonification of the beamline as it interacts with various targets. The experiment is devised to result in audible outputs determined by the particle content and properties of the beamline. Viability will be determined upon data collection, utilising statistical measurement and audience engagement as a gauge. If the experiment is successful and viability is demonstrated, results will be made available online, so musicians and composers can use and modify the data and software for their own purposes.

1. Introduction

Sonification is a significant aspect of data communication, evident in its widespread history¹ - from a clock's ticking to denote passing seconds, to a Geiger counter's clicking symbolising radiation. It's essential as a means of expressing data through its accessibility, not requiring detailed prior knowledge to engage. Thanks to modern technological advances, complex data sonification is possible, and with it comes new applications for the process. One such application is sonification for musical composition, a recent practice focused on combining artistic interpretations with data outputs. An early example of this is Alvin Lucier's "Music for a Solo Performer" (1965)², utilising an electroencephalogram to create music. In the scope of particle physics, several prominent examples exist, but the field is still underdeveloped. Projects such as Dr. Juliana Cherston's "Quantizer"³, for example, demonstrate potential for serious compositional sonification in physics, yet most still view it as a gimmick. The project aims to address this, and details a plan to assess sonification of the T9 beamline at CERN as a tool for musical composition, utilising targets in the beam's path to steer data into producing music.

2. Motivations

Art and science are often seen as vastly distinct subjects, especially within highschool education, making it challenging to study them simultaneously. We disagree with this notion and chose to enter BL4S to prove that the two disciplines can go hand-in-hand. Whilst a small team of only five members from two countries, we are highly motivated by curiosity and have overcome numerous challenges during the developmental process. We hope to extend our physics knowledge and skills through our passion for music.

¹ Kramer, Gregory: *Auditory Display: Sonification, Audification, And Auditory Interfaces*.

² Link to performance:  Alvin Lucier: Music for Solo Performer (1965)

³ Link, courtesy of Dr. Juliana Cherston: <http://quantizer.media.mit.edu/mobile/>

3. Method

3.1. Software design

The software is a built-for-purpose parameter mapping program. It consists of a Python script that accepts inputs from a .csv file, selects the desired parameters, assigns them musical values and exports the product as a .MIDI file. It can be run from live data (particle-by-particle) as it's added to the file, or from averaged data (from distributions). The mapping program can, in principle, be used with a wide variety of data inputs with various parameters. In the specific case of the T9 beamline, we have chosen four parameters to map to musical concepts, illustrated in Figure 3.1.

Parameter	Musical Notation
Time of incidence	Order
Energy	Pitch
Coordinate of incidence	Instrumentation
Velocity	Dynamics

Figure 3.1: Table indicating parameters and corresponding musical properties. Notation is subject to the artistic choices of the composer, and can be easily altered if desired.

An abstract of the program (Figure 3.2) and example of mapping (Figure 3.3) are also provided.

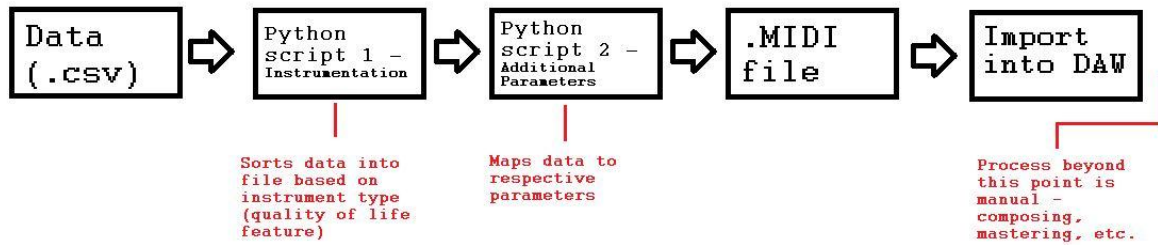


Figure 3.2: Abstract of the sonification program.

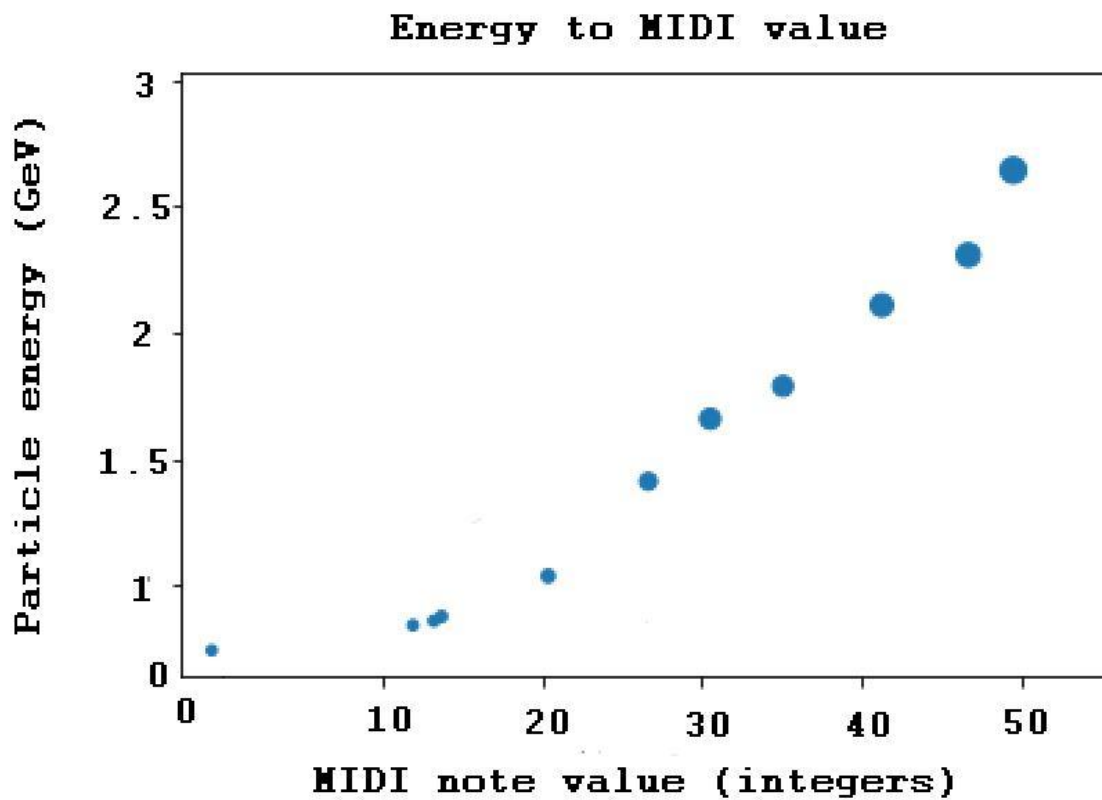


Figure 3.3: Example mapping of particle energy to pitch. This data is hypothetical. It serves to illustrate the mapping process of data, and the predicted results of the experiment.

3.2. Experiment design

Figure 3.4 details experiment layout. Scint2 and Scint3 will determine time of incidence and velocity in a time of flight module. Coordinate of incidence will be determined by DWC2, and energy by Calorimeter1. The positive beam is to be run at 3GeV.

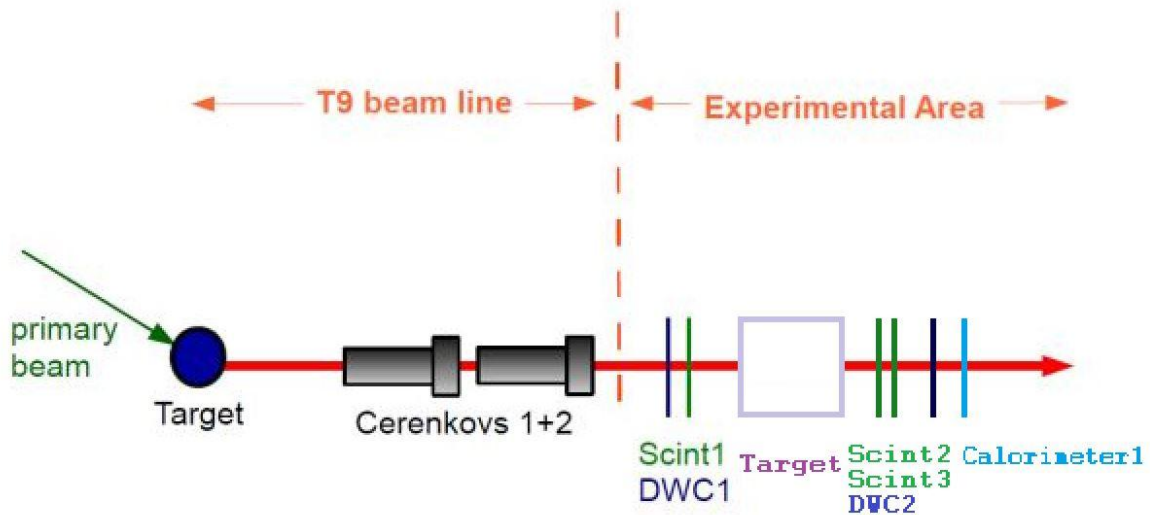


Figure 3.4: Layout of detectors for the experiment. Scint1, DWC1, and Cherenkovs 1+2 are not to be used.

The primary particles of interest for the experiment are protons (p), positive pions (π^+), positive kaons (K^+), and positrons (e^+). Targets are decided by their ability to influence outputs in a desirable way (in this context, to alter pitch). The experiment is to be conducted with three different target configurations, detailed below:

1. Configuration 1 - no target. Used to gather control data.
2. Configuration 2 - additive target. The aim is to trigger production of K^+ in the beam to reduce particle count disparity. This will be achieved by placing a tin target in the beam to produce π^+ ⁴. These will then interact with a second, proton-rich target (such as hydrogen). Conservation laws state that the interaction of π^+ and p can result in the production of K^+ through the strong force (Figure 3.5). The increase in K^+ will theoretically result in greater pitch variety within the melody than the control.
3. Configuration 3 - subtractive target. The aim is to trigger production of antiparticle counterparts to particles within the beam to reduce the count incident at the calorimeter through annihilation. In the context of the T9 beamline, antiprotons, electrons, and π^- are desired. To produce antiprotons and π^- , a proton-rich metal

⁴ Determination of target based upon research from the HARP collaboration:
<https://cds.cern.ch/record/1058460/files/EPJC.53.177-204.pdf>

target (such as iridium) will be used⁵. The protons from the beamline will collide with those in the target and produce secondary particles, including antiprotons and π^- . To annihilate the positrons, an element with low-electron affinity is to be introduced, such as Argon. Count incidence of K^+ at the end calorimeter should theoretically be proportionally greater than annihilated particles, resulting in less pitch variation in the melody.

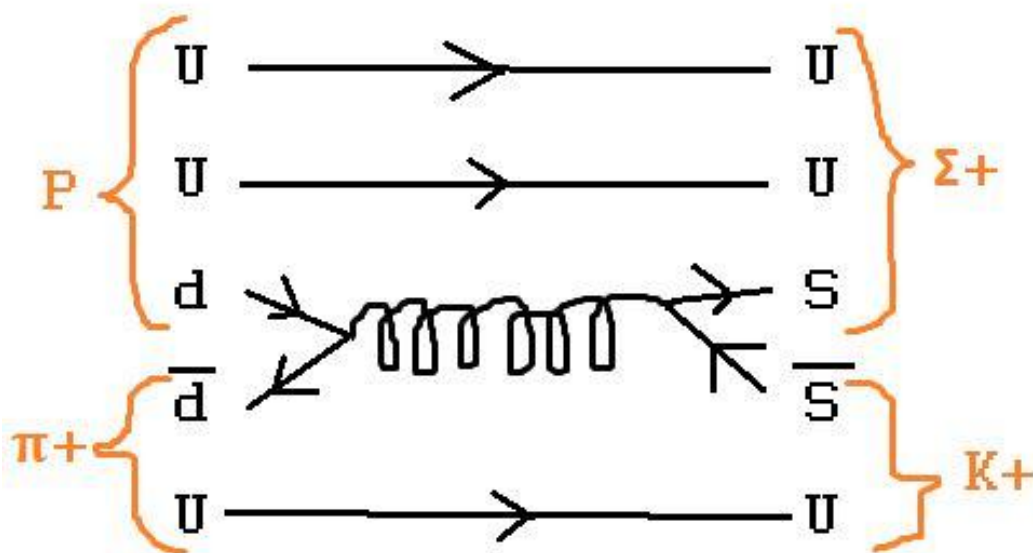


Figure 3.5: Feynman diagram illustrating the interaction of a proton and π^+ through the strong force, producing Σ^+ and K^+ particles.

4. Analysis of results

To assess viability as part of a compositional tool, success of targets will be determined through hypothesis testing. Using the control as a basis, critical regions can be decided ($\alpha = 5\%$). If target readouts fall within these regions, the output is significantly different, therefore successful. Surveys can be conducted measuring audience engagement with outputs to further analyse viability.

⁵ Based on, in part, Möhl, D. Production of low-energy antiprotons. *Hyperfine Interactions* 109, 33–41 (1997). <https://doi.org/10.1023/A:1012680728257>

5. Further developments

Beyond this project, the experiment could be developed further. As a compositional tool, it could be used to perform live music for art projects such as Dr. James Beacham's "Gray: An Exercise in LHC Data Sonification"⁶, which played alongside a live noise band in 2016. It also has potential as an educational tool, engaging audiences in an approachable way that generates interest. Implications outside of composition are recognised, as an analysis tool for scientists with impaired vision or as accompaniment to visual data.

6. What we hope to take away

Partaking in BL4S has proved invaluable to us, helping us develop practical scientific skills and allowing us to make connections with each other despite geographical differences. We hope to take these experiences with us as we grow as scientists, share knowledge we gained with our peers, and continue fostering a curiosity for the unknown.

7. Outreach proposal

The nature of our project lends itself to public outreach—music is fun, accessible, and easy to interpret by non-specialist audiences. Additionally, the environments our team are from have lacklustre physics education; in rural England, agriculture dominates the job and education sphere, and in Turkey, knowledge of particle physics among students is limited, resulting in overall hesitation towards physics. As such, a low barrier to entry is crucial for engaging audiences without overwhelming them. With this in mind, we plan to host two sister outreach events- one in Turkey and another in England - to make physics more approachable to audiences. We will use our sonification engine to process data and make sample music, then invite audiences to both campuses to watch a brief talk on the project's development, and to interact with the data themselves (altering parameters, selecting datasets, etc) in an interactive environment. We will use simplified terms and broad metaphors to ensure comprehension, and will provide participants with a leaflet with weblinks attached to encourage further investigation into physics. We aim to emphasise the novelty interest associated with sonification, with hope that it makes physics seem less daunting and complex and helps it seem enjoyable and accessible.

⁶ Link, courtesy of Dr. James Beacham:
<https://jbbeacham.com/gray-an-exercise-in-lhc-data-sonification>

8. Acknowledgements

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